CMS RPC Background studies in LHC Run 2 and Run 3

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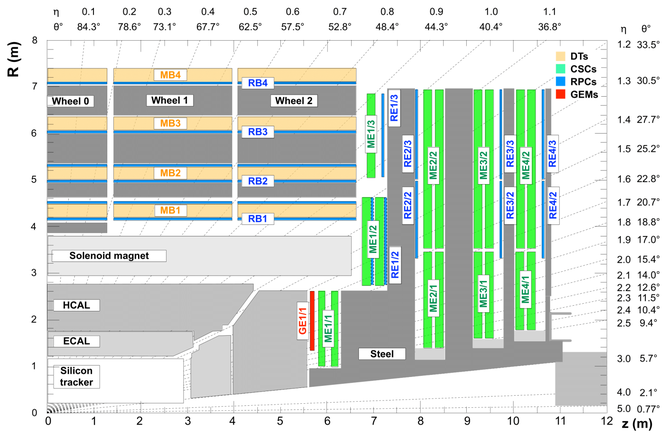
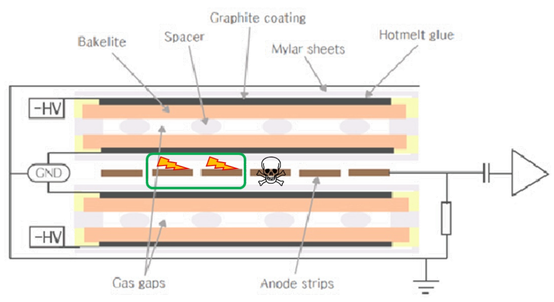
Introduction

- Optimal muon reconstruction → higher trigger quality
- Ensured by redundancy in the Muon System
- **Threat: background rate**

$$\text{Hit Rate} = \frac{1}{n \cdot \Delta t \cdot A} \sum_{bx=bx_1}^{bx_n} N_{Clusters}(bx, \Delta t)$$





Nomenclature

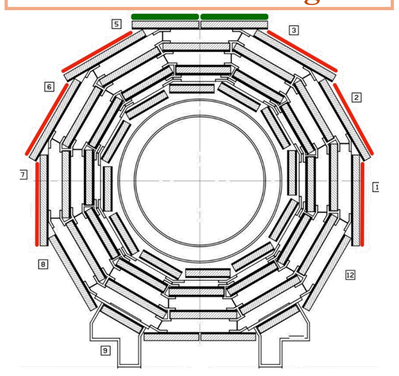
- Dependence on the LHC filling scheme:
  - → **Colliding** (C)
  - → **Non-Colliding** (NC)
  - → **Pre-Beam** (PB) e **Beam-Abort** (BA)
- 3 background definitions:
  - → $B_{INCLUSIVE} = \frac{n_{PB}B_{PB}+n_{C}B_{C}+n_{NC}B_{NC}+n_{BA}B_{BA}}{n_{PB}+n_{C}+n_{NC}+n_{BA}}$
  - → $B_{DELAYED} = \frac{n_{PB}B_{PB}+n_{NC}B_{NC}+n_{BA}B_{BA}}{n_{PB}+n_{NC}+n_{BA}}$
  - → $B_{PROMPT} = B_C - B_{DELAYED}$

with n=number of bunches, B=hit rate

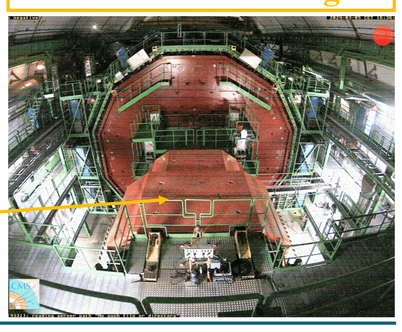
Run 2 → Run 3 differences

1. Centre-of-mass energy
2. New beam-pipe (LS2) [1]
3. New Barrel Shielding (LS2) [2,3]
4. New Forward Shielding (2023 YETS) [4]
   - → Negative side of experimental cavern

Barrel Shielding



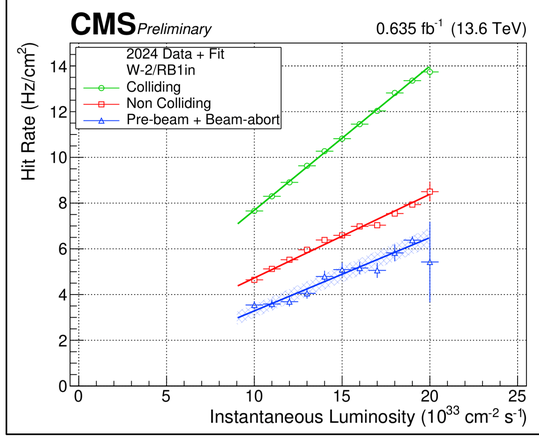
Forward Shielding



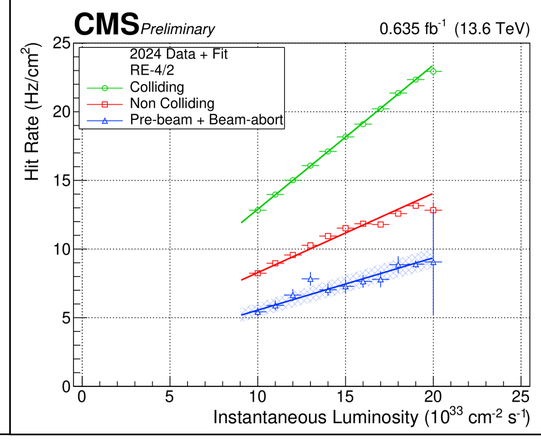
Background-luminosity dependency

- Backgrounds: ***Colliding***, ***Non Colliding***, ***Pre-Beam*** and ***Beam-Abort*** (together)
- Linear dependence on instantaneous luminosity

Barrel



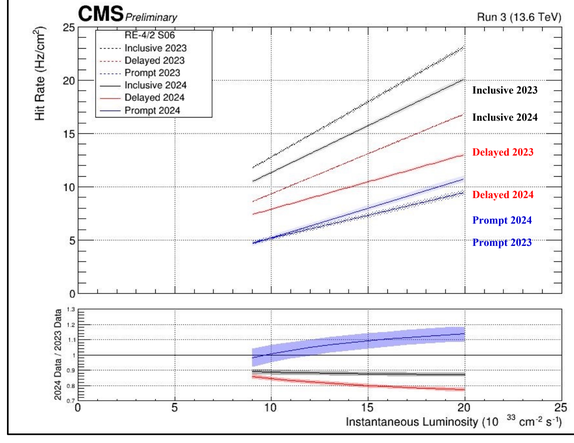
Endcap



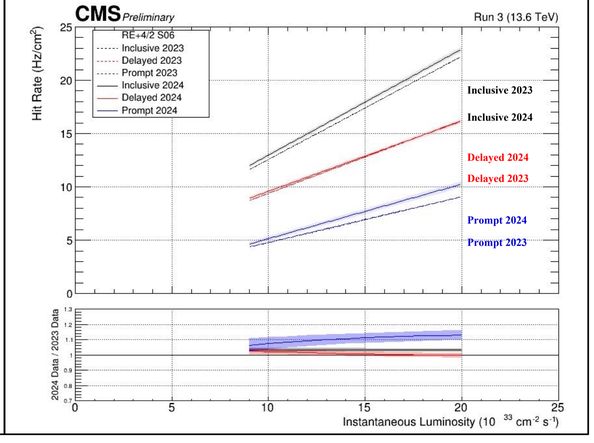
Effectiveness of the New Forward Shielding

- Clear reduction in ***Inclusive*** and ***Delayed*** backgrounds (− Endcap) → up to ~**80**%
- ***Prompt*** background increases in both endcaps
  - → Possible systematic effect arising, due to different filling schemas used for 2023 and 2024 data

Negative Endcap



Positive Endcap

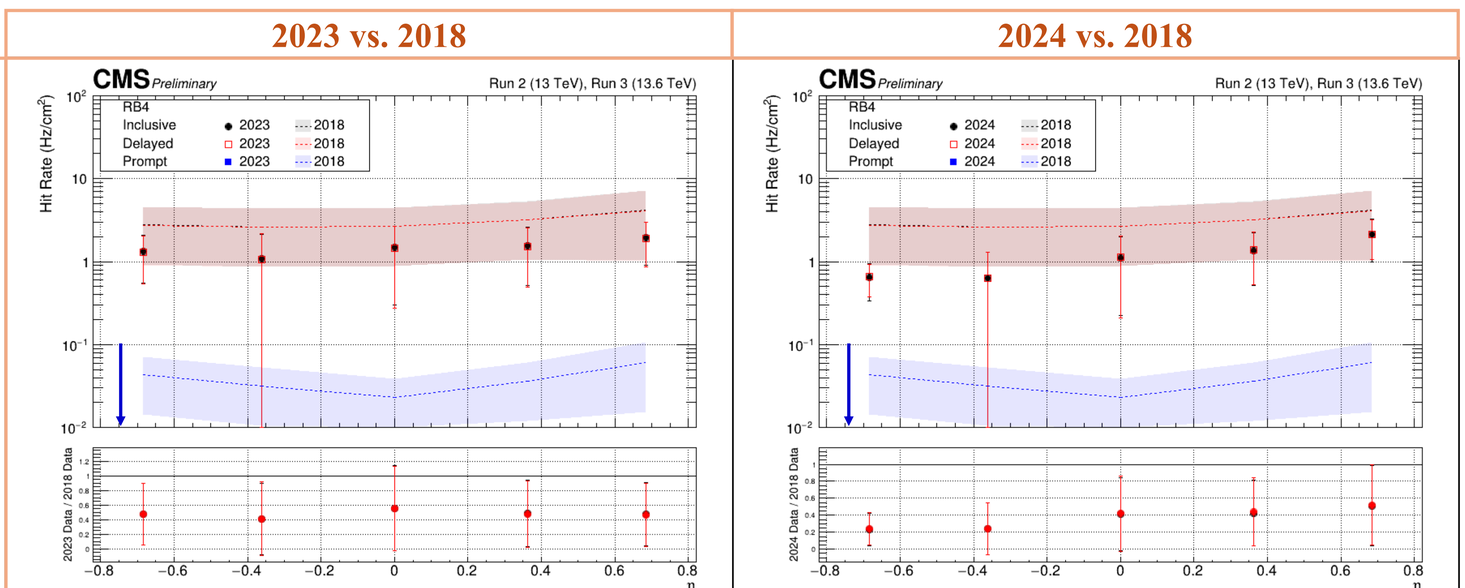


Run 2 vs. Run 3

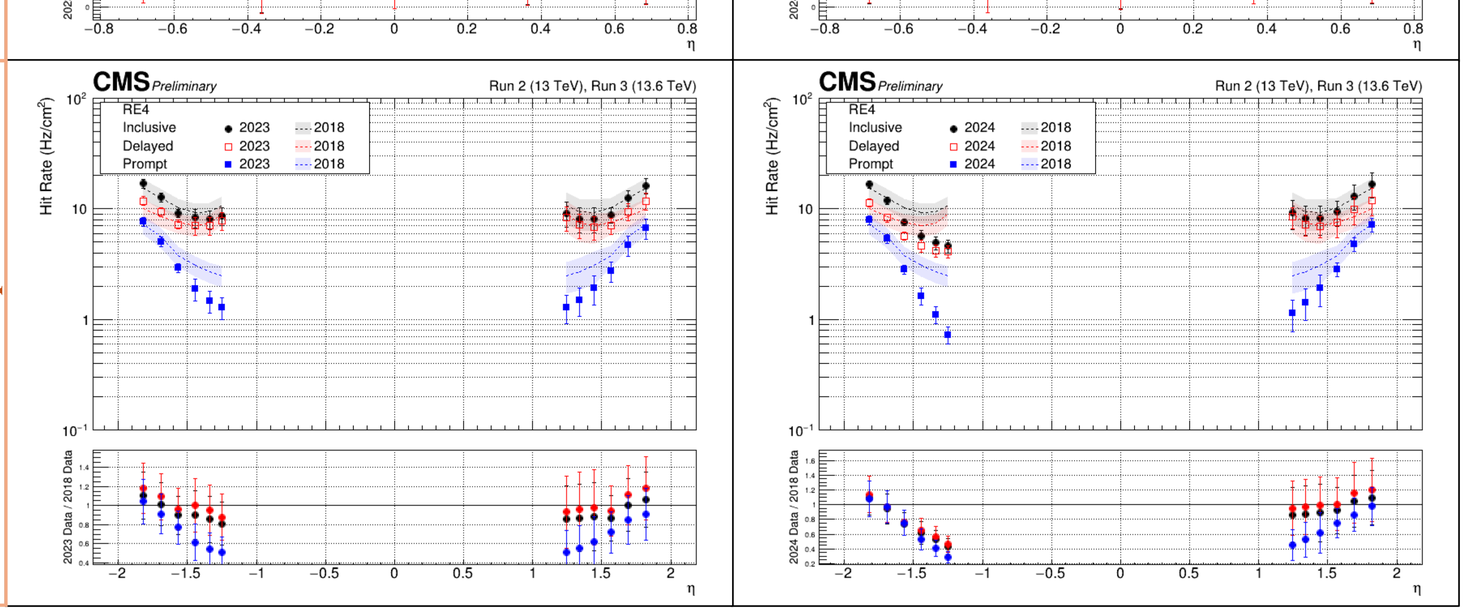
- CMS RPC Run 2 background studies can be found at [5].
- The offline Hit Rate vs. η at a fixed value of instantaneous luminosity ($1\times10^{34}cm^2s^{-1}$) is plotted for the outermost chamber in the Barrel (top row) and Endcap (bottom row). The results obtained in Run 3 (2023 data on the left and 2024 data on the right) are compared to 2018 data (the bands show the standard deviation of the hit rate over the phi-sectors) .
- In the outermost station of the Barrel
  - Barrel shielding + new beam-pipe
    → ***Delayed*** reduced up to ~**50**%;
  - + New Forward Shielding
    → ***Delayed*** reduced up to ~**20**% in the negative side;
  - Blue Arrow to show that ***Prompt*** is negligible in Run 3.
- In the outermost station of the Endcap
  - Barrel shielding + new beam-pipe
    → compatible ***Delayed*** values;
  - + New Forward Shielding
    → ***Delayed*** reduced up to ~**40**% in the negative side;
  - ***Prompt*** progressively reduced moving outwards.

2023 vs. 2018 | **2024 vs. 2018**

Barrel



Endcap



Summary and Outlook

- Background studies:
  - → Study the performance and robustness of our detectors;
  - → Useful to understand if our detectors are ready for High-Lumi LHC and to determine future upgrade choices.
- First extensive Run 2 vs. Run3 study performed.
- Next Steps:
  - → ***Phase-2 Upgrade***: new detectors in the forward region, to inspect the most irradiated regions;
  - → ***High-Lumi projections***: from these studies, we could predict the background rate at High-Lumi conditions.

References

[1] https://cms.cern/news/installation-beam-pipe-delicate-surgical-operation-heart-cms-experiment
[2] https://cds.cern.ch/record/2861531/files/DP2023_033.pdf?version=1
[3] https://cms.cern/news/shielding-outer-muon-barrel-chambers-cms-hl-lhc-preparing-umbrella-rain
[4] https://cms.cern/news/new-forward-shielding-installed
[5] F. Carnevali *et al.* [CMS Muon] ”RPC background studies at CMS experiment”, DOI:10.1016/j.nima.2023.168266

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